REPORT ON PHYSIOLOGY.

By H. P. Bowditch, M.D.

Electrical Phenomena of Nerves and Muscles.

Untersuchungen über den Erregungsvorgang im Nerven-und Muskelsysteme. Bernstein. Heidelberg. 1871.

The electrical phenomena of nerves and muscles, first clearly described by Du-Bois Reymond in his work on Animal Electricity, published in 1848, have since then attracted the attention of many able observers, of whom none have been more successful than Professor Bernstein. This investigator has made important contributions to our knowledge of the electrical changes which characterize the functional activity both of nerves and muscles. To make an account of his observations more intelligible, a few words in regard to the fundamental phenomena may be permitted.

In living nerves and muscles, the electrical state is such that if a connection is made between any point of the normal surface, or of a longitudinal section, and any point of a transverse section (or, in the case of a muscle, of the tendon, which represents the transverse section of all the fibres), and a galvanometer is brought into the circuit which forms this connection, it is found that an electrical current is present, running from the longitudinal section through the galvanometer to the transverse section. In other words, every point in the *longitudinal* section of a nerve or muscle is electrically positive with reference to every point in the *transverse* section of the same. Now, if the nerve or muscle be brought into a state of functional activity (either by mechanical, chemical or electrical stimulation), it is found that the current passing through the galvanometer is diminished in intensity, i. e., the difference between the electrical conditions of the longitudinal and transverse sections becomes less. This is known as the "negative variation" of the nerve- or muscle-current.

By means of extremely delicate and ingenious instruments, it has been shown that the negative variation is first felt in those parts of the nerve or muscle which are in the immediate neighborhood of the point where the stimulus is applied, and that it afterwards makes its appearance at points sucessively more and more distant, while disappearing at the points where it had first appeared. In other words, the negative variation is transmitted with a wave-like motion along the nerve or muscle in both directions from the point stimulated.

The nature of this wave-like motion has been carefully investigated by Bernstein, who has determined, both for muscles and nerves, the rate of transmission, the length and duration of the wave. The following are the mean values obtained in experiments on frogs:—

Wave of Negative Variation.	Muscle.	Nerve.
Rapidity.	2·927 met. in 1″	27·7 met. in 1″
Length.	10 mm.	18·7 mm.
Duration.	0·0039″	0·00068″

From this table, it will be understood that, when a muscle is stimu-

lated at any one point, the electrical condition of the muscle at that point is changed, that this changed electrical condition is propagated wave-like in both directions at a rate of 2·927 metres in 1″, that each portion of the muscle requires 0·0039″ to go through this changed condition and return to its normal state, and that the distance measured on the muscle between a point which is just entering upon and one which is just leaving this changed electrical condition is 10 mm. The same may be said of nerves, with a change of the figures.

Now, the rapidity of the wave of *negative variation in nerves* agrees quite closely with the value found by Helmholtz for the rapidity of *nerve force*, viz., 26·4 metres in 1″. (This value was obtained by noting how the time elapsing between the irritation of a nerve and the consequent contraction of the muscle attached to it varied according as the stimulus was applied at a distance from or close to the muscle.*) This close correspondence of the two phenomena in regard to rapidity, together with the fact that the height of the wave of negative variation, i. e., the amount of the electrical change, increases with the intensity of the stimulation, clearly indicates that a very close relation exists between the manifestation of nerve force and the change in the electrical condition of the nerve, and may even be considered as furnishing a sufficient reason for regarding the latter as a measure of the former. This is important, for we are thus furnished with a means of determining whether a nerve is functionally active or not, by an examination of the nerve itself, instead of inferring the activity of the nerve from that of the organs (muscles, glands, &c.) to which it is distributed.

Consider next in what way muscular contraction is related to the electrical phenomena of muscle. When any point of a long muscle is irritated, a contraction takes place at that point, i. e., the muscle becomes, at that part, thicker and shorter, and this change of form is transmitted, wave-like, along the muscle in both directions from the point stimulated. The rapidity with which this contraction wave moves along the muscle, may be investigated by placing delicate levers at different points on the surface of the muscle, and allowing their extremities to record their movements on a revolving cylinder covered with smoked paper. The time elapsing between the rise of the different levers measures the rapidity of the contraction wave passing under them. Measurements, made in this way by Aeby† and Marey,‡ showed that the contraction wave of the frog's muscle moves at the rate of about one metre in 1″. This rapidity is only about one-third of that of the wave of negative variation, as given above. It would, therefore, seem that the connection between functional activity and electrical condition is not so close in the muscle as in the nerve. Bernstein, however, in a series of carefully conducted experiments, has obtained the following figures as mean values of many experiments :—

	Wave of muscular contraction.
Rapidity, - - - - - -	3·8 metres in 1″
Length, - - - - - - -	289 mm.
Duration, - - - - - -	0·0784″.

* See this JOURNAL, January 5th, 1872, p. 54.

† Fortpflanzungsgeshwindigkeit dei Reizung in der quergestreiften Muskelfazer. Braunschweig. 1862.

‡ Du mouvement dans les fonctions de la vie. Paris. 1868.

It will thus be seen that the rapidity of the contraction wave is quite as great as that of the wave of negative variation. One reason why Aeby and Marey obtained a smaller value is, probably, that they failed to take into account the diminution which the contraction wave undergoes as it passes along the muscle. Bernstein regards the two rates as identical, and considers the difference in the figures which he obtained as due to errors of observation, thus recognizing the same relation between the phenomena in muscles as in nerves.

Still more conclusive evidence of the close connection existing between the phenomena is obtained by an examination of the length and duration of the waves in question. According to the above values, a contraction wave has a length of 289 mm., moves at the rate of 3·8 metres in 1″, and occupies 0·0784″ in passing a given point. Now, if any point of a muscle be irritated by induction shocks 13 times in 1″, these contraction waves will follow each other so rapidly that one wave will reach a given point of the muscle just as its predecessor is passing away from that point. In other words, each muscular element will have no sooner returned to a state of repose after the passage of one contraction wave than it will be again brought into activity by the arrival of the following wave. If the irritations succeed each other with somewhat greater rapidity (e. g., 20 times in 1″), the contraction waves will overlap each other, and the muscular elements brought into activity by one wave will not have time to return to a condition of repose before the arrival of another wave, i. e., the whole muscle will be in a state of continual or tetanic contraction. This agrees perfectly with the observation that a frog's muscle may be tetanized by irritating it 18 or 20 times in 1″.

Now, if the irritations follow each other still more rapidly, there is at first no change in the nature of the contraction. The tetanus merely becomes more and more perfect by the more complete overlapping of the contraction waves. But when the frequency of the irritation reaches about 300 in 1″, it is found, according to Bernstein, that a single momentary contraction is produced at the *beginning* of the irritation, while *during* the irritation the muscle remains at rest; i. e., the muscle stimulated 300 times in a second fails to respond by a contraction, though the same stimulus, when applied less frequently, is sufficient to produce tetanus. If, now, the intensity of the irritation is increased, while the frequency is kept constant at 300 in 1″, a feeble tetanus is found to follow the momentary commencement contraction. This tetanus may be still further increased by increasing the intensity of the irritation; but, if the frequency of the irritation be increased, the tetanus disappears and the muscle remains at rest. It will thus be seen that when a muscle is stimulated 300 times and upwards in 1″, it will always respond by a momentary contraction at the *beginning* of the stimulation, but that, *during* the stimulation, a tetanus will be produced only by a more intense stimulus than would be necessary if it were less frequently applied. In other words, the more rapid the stimulation (above 300 in 1″), the more intense must it be in order to produce tetanus. These results are obtained equally well whether the irritation is applied to the nerve or to the curarized muscle, which indicates that they depend upon peculiarities of the muscle and not of the nerve.

Now, if we consider the course of the wave of negative variation of

a muscle, we shall find an explanation of the above phenomena. According to the values above given, this wave has a length of 10 mm., and moves at the rate of 2.9 metres in 1″. Therefore if a muscle is irritated 300 times in 1″, the waves in question will follow each other so rapidly that they will begin to overlap each other, and the more they overlap, the more complete will be the state of negative variation in which the muscular elements are kept. In other words, the more rapid the irritation (above 300 times in 1″), the more permanent will be the electrical condition of the muscle, since the muscular elements have less time to return to their normal condition between the passage of the successive waves. The fact that the rapidity of irritation which causes the overlapping of the waves of negative variation is about the same as that which causes the appearance of the commencement contraction, and the disappearance of the tetanus, leads Bernstein to the conclusion that every muscular element must go through the condition of negative variation as a necessary preliminary to contraction, and that the extent (or, more strictly speaking, the suddenness) of this change of electrical condition determines the extent of the contraction.

Bernstein's theory may then be briefly stated as follows. If any point of a muscle be irritated with a single induction shock, a wave of negative variation, 10 mm. in length, starts immediately from the point irritated, and moves in both directions along the fibre, at the rate of about 3 metres in 1″. This is followed, after an interval of about .01″ (period of "latent irritation" of Helmholtz), by the contraction wave, having a length of 289 mm. and a rapidity the same as that of the wave of negative variation. If irritations follow each other with a rapidity greater than 20 and less than 300 in 1″, the contraction waves overlap each other, while the waves of negative variation (or "irritation waves," as Bernstein calls them) do not, and the muscular elements, in consequence of the incessant change of their electrical condition, are kept in a state of continued activity, and tetanus results. If irritations succeed each other oftener than 300 times in 1″, the irritation waves overlap each other, and the *first* wave is, therefore, the only one which exerts its full effect on the muscular elements, the effect of the other waves being diminished in proportion to the completeness of the overlapping. The result is, therefore, a strong "commencement contraction" and a tetanus enfeebled or entirely absent.

If a similar relation between the rapidity of irritation and functional activity be supposed to exist in nerves, we should expect that if a nerve were irritated about 1600 times in 1″, the irritation waves would overlap each other and the activity of the nerve be diminished. The question is difficult to decide experimentally, for the contraction of a muscle cannot be used as an indication of the activity of the nerve distributed to it, since muscles, as explained above, cease to contract at a rapidity of irritation far less than 1600 in 1″. Von Wittich has shown *(Pflüger's Archiv,* ii. p. 329) that when the skin is irritated mechanically from 1728 to 3840 times in 1″ the separate irritations blend into one continuous impression. Bernstein is inclined to regard this as the effect of the overlapping of irritation waves, and, considering that we do not know the length of the irritation wave in human nerves, the agreement of the figures is, perhaps, as near as could be expected.

In this connection should be mentioned the experiments of Grün-

hagen, on intermittent irritation of nerves *(Pflüger's Archiv*, vi. p. 157). The apparatus employed was a steel spring rubbing against the edge of a revolving toothed wheel, by which means from 1460 to 10980 interruptions in 1″ could be produced. This interruptor was introduced either into the same circuit with the nerve, or into a side circuit from the same battery. The result was to irritate the nerve by a rapid succession of galvanic currents of exceedingly short duration. These experiments cannot, therefore, be compared with those of Bernstein, in most of whose observations the irritation was produced by induction shocks caused by the making and breaking of a mercury contact by means of the vibrations of a steel spring. It is interesting, however, to notice that the results were, in general, the same, though Grünhagen adopts a different explanation from that of Bernstein. Both observers found that the stronger the single irritations were, the more rapidly must they follow each other in order to insure the disappearance of tetanus.

Setchenow also studied the effect of irritations rapidly following each other *(Pflüger's Archiv*, v. p. 11), using for this purpose induction shocks produced by the interruptor of Froment *(Comptes Rendus*, 1847). He observed essentially the same phenomena ("commencement contraction," disappearance of tetanus, &c.) that were noticed by Bernstein, but, inasmuch as they only occurred when the irritation was made by closing the primary circuit, the nerve being included in the secondary circuit, and were not observed when the irritation was caused by the breaking of a side current in the secondary circuit, Setchenow regards the phenomena as physical in their nature, and dependent upon the construction of the apparatus rather than upon peculiarities of the nerve.

In answer to this criticism, Bernstein *(Pflüger's Archiv*, v. p. 318) calls attention to the fact that in his experiments the phenomena in question *were* observed when the irritation was produced by breaking a side current in the secondary circuit, and, consequently, cannot be explained by physical processes in the electrical apparatus. He attributes the discrepancy between his own results and those of Setchenow to difference in the apparatus employed, and regards as objectionable any instrument which (like Froment's) makes and breaks a circuit by the vibration of a spring against a solid support, for the spring, being thus prevented from completing its vibration, will not vibrate with regularity.

Electrotonus.

Bernstein has also recently contributed to our knowledge of electrotonic changes of irritability *(Pflüger's Archiv*, viii. p. 40). For a statement of the fundamental phenomena of electrotonus, suffice it to say that when a constant current of electricity is conducted through a nerve, the irritability is increased in the neighborhood of the kathode, and diminished in that of the anode, i. e., an irritation applied to the nerve near the point where the constant current enters must be stronger than if applied near the point where it leaves the nerve, in order to produce a contraction of the muscle to which the nerve is distributed. Now, as the negative variation of the nerve current is regarded, for the reasons given above, as the measure of the functional activity of the nerve, we should expect it to be diminished in anelectrotonus and increased in katelectrotonus. In other words, we

should expect that an irritation, applied to a nerve near the kathode of the polarizing current (i. e., the current used to produce the electrotonic changes of irritability), would produce a more intense wave of negative variation than an irritation applied near the anode. This is found to be the case provided the polarizing current is applied at a considerable distance from the point where the negative variation is examined and irritations of feeble intensity are used. When, on the contrary, the polarizing current is applied near the point where the negative variation is examined and strong irritations are used, the opposite is found to be true, i. e., the negative variation increases in anelectrotonus and decreases in katelectrotonus.

To explain this apparent contradiction, and to determine whether anything analogous could be observed when a muscular contraction is used as an indication of nervous activity, was the object of Bernstein's recent investigations. The experiments consisted in conducting a polarizing current of constant intensity through a frog's nerve, and then applying successive irritations, viz., induction shocks of gradually increasing intensity, in the neighborhood of one of the poles. The contractions of the muscle, under the influence of these stimuli applied to the nerve, were recorded and compared with those which the same muscle executed when the nerve was simply irritated by induction shocks without the use of any polarizing current. The result showed that as long as the induction shocks were of feeble intensity, the ordinary phenomena of electrotonus manifested themselves, i. e., increased irritability near the kathode, and diminished irritability near the anode. When, on the other hand, the induction shocks were made strong enough to produce the maximum contraction of the muscle, the opposite result was obtained, i. e., a greater contraction was produced by an irritation near the anode, and a feebler contraction by an irritation near the kathode. The law of electrotonus is, therefore, according to Bernstein, to be stated as follows:—

When a constant current flows through a nerve, it is found that at the positive pole the production of a state of functional activity is rendered more difficult, so that feeble irritations have less effect than in the normal condition (anelectrotonus); but the maximum of activity which can be produced by strong irritations is increased. At the negative pole, on the contrary, the production of a state of activity is rendered easier, so that feeble irritations have greater effect (katelectrotonus); but the maximum of activity which can be produced by strong irritations is lessened. In other words, the nervous molecules in anelectrotonus are less easily moved, but, when set in motion by a sufficient force, are capable of producing greater effects than in the normal condition. The opposite is true in katelectrotonus.

This modification of the law of electrotonus will undoubtedly find important applications in electro-therapeutics.

Hermann (*Pflüger's Archiv*, viii. 258) criticizes Bernstein's views on electrotonus, and, on repeating his experiments, fails to obtain, by the use of strong irritations, an increased contraction in anelectrotonus.

Bile.

V. Wittich. Zur Physiologie der menschlichen Galle. *Pflüger's Archiv*, vi. 181.

Röhrig. Experimentelle Untersuchungen über die Physiologie der Gallenabsonderung. *Stricker's Jahrbücher*, 1873, p. 240.

Munk. Ueber den Einfluss sensibler Reizung auf die Gallenausscheidung. *Pflüger's Archiv*, viii. 151.

Von Wittich made observations on the human bile obtained from a patient with a biliary fistula, caused by the impaction of gall stones in the cystic duct. For some time after the opening of the fistula, the whole of the bile was discharged through it, none entering the intestines, as was evident from the appearance of the fæces. The total quantity discharged daily was 532 cc., an amount considerably below Bidder and Schmidt's estimate (1300 grammes), derived from experiments on dogs, but falling within the limits assigned by Ludwig for the daily secretion of the human bile (160 to 1200 grammes).

Von Wittich also examined the bile thus obtained with regard to its power of converting starch into sugar, and found that it possessed this power in a high degree. In consideration, however, of the wide distribution of sugar-ferments through the body, it seems quite possible that the bile may have acquired this property from some of the tissues with which it came in contact in its passage through the open wound.

The method of experimenting recommended by the author is similar to that proposed by Grünhagen to demonstrate the effect of pepsin. On a coarse filter, kept by a water-bath at a temperature of 40° to 50° C., a stiff starch paste was placed. The addition of a few drops of a solution of the sugar ferment obtained from the bile soon caused a fluid to pass through the filter, and, in this fluid, sugar could be readily detected.

Röhrig has made some experiments on the mechanism of the secretion of bile, the subjects of the observations being dogs and rabbits, curarized and kept alive by artificial respiration. A canula was placed in the hepatic duct, the cystic duct was tied, and the rate of the secretion was determined by counting the drops as they fell from the canula. The following are the most important results :—

I. Compression of the portal vein and the hepatic artery at the same time stops the secretion at once. A compression lasting more than one minute produces fatal results.

II. Compression of the portal vein alone diminishes the secretion greatly, but does not stop it.

III. Compression of the hepatic artery alone diminishes the secretion slightly.

IV. Ligature of the aorta, below the diaphragm, diminishes and finally stops the secretion.

V. Ligature of the aorta, below the cœliac axis, increases the secretion.

VI. Ligature of the inferior vena cava, above the hepatic vein, diminishes and finally stops the secretion. This shows that the secretion does not depend exclusively on the height of the blood-pressure in the capillaries of the liver, for ligatures applied as in V. and VI. must, in both cases, increase this pressure, while the secretion is in one case increased and in the other diminished.

VII. Chemical, mechanical and electrical irritation of the mucous

membrane in all parts of the alimentary canal, and of the liver itself, has no effect on the secretion of the bile.

VIII. Injection into the stomach of products of digestion, taken from the alimentary canal of another animal, increases the secretion.

IX. Diarrhœa is often accompanied by a very rapid secretion.

X. Cathartics, viz. croton oil, colocynth, jalap, aloes, rhubarb, senna, Epsom salts, calomel and castor-oil, injected into the small intestine, cause an increased secretion of bile, which is apparent before the purgative action begins. (This result is diametrically opposed to that obtained by the Edinburgh committee of the British Medical Association, appointed to investigate the action of mercury and other drugs on the biliary secretion. These observers found that purgation, however produced, invariably diminished the quantity of the biliary secretion.) Senna and rhubarb, when injected into the mesenteric veins, increase the secretion of bile, which seems to show that these two drugs act as chologogues independently of their cathartic power. That cathartics, however, may act indirectly as chologogues, in consequence of their increasing the vascularity of the intestines, seems evident from the following results of experiments on the nervous system :—

XI. Section of the splanchnic nerves causes a temporary increase of secretion.

XII. Section of the cervical cord causes increased secretion (but not if a cathartic has been previously given).

XIII. Irritation of sensitive nerves diminishes the secretion.

XIV. Suspension of respiration causes at first a diminished secretion, corresponding to a rise of blood tension, then an increased secretion, corresponding to a fall of blood tension, and, finally, a second diminution of the secretion, due, apparently, to the altered quality of the blood.

XV. Strychnia causes at first a slow and afterwards a rapid secretion, corresponding to a rise and subsequent fall of blood tension.

In the above observations (XI.–XV.), it will be noticed that all those operations which are known to cause contraction of the intestinal vessels (indicated by a rise of blood tension) diminish the secretion of bile, while those which dilate the same vessels have the opposite effect. It is therefore probable that the chologogue action of cathartics may be partly dependent upon the changes produced in the intestinal circulation.

The author confirms the observation of Schmulewitsch *(Ludwig's Arbeiten*, 1868, p. 113) that an excised liver, through the vessels of which defibrinated blood is conducted, continues to secrete bile for some time after its removal from the body. If a one per cent. solution of common salt is used instead of defibrinated blood, no secretion takes place, showing that the fluid in question cannot be simply bile retained in the gall-ducts and pressed out mechanically by the injection into the bloodvessels. The latter view is, however, maintained by Pflüger,* who supports it by experiments similar to those of Röhrig, except that he used a three per cent. instead of a one per cent. solution of salt. How these results are to be reconciled is not clear.

Munk's experiments were performed on curarized rabbits, in the same way as Röhrig's. He finds that irritation of the spinal cord (either direct or indirect through sensitive nerves) causes,

* Pflüger's Archiv, iv. p. 54.

at first, an increased and afterwards a diminished secretion of bile, instead of simply a diminution, as observed by Röhrig. (See above, XIII.) He thus confirms former observations of Heidenhain, who attributed the primary increase of secretion to the contraction of the muscular walls of the gall-ducts pressing out the bile contained there, and the secondary diminution of secretion to the diminished flow of blood through the capillaries of the liver. Munk demonstrates that the splanchnic nerves are the channel through which both of these effects are produced, for irritation of these nerves causes both the primary increase and the secondary diminution of secretion, and, after section of these nerves, both direct and reflex irritation of the cord remain without effect.

Blood Globules.

Malassez. *De la Numeration des Globules rouges du Sang.* Paris: 1873.

Manassein. *Ueber die Dimensionen der rothen Blutkörperchen unter verschiedenen Einflüssen.* Berlin: 1872.

Malassez has invented a method by means of which the number of red globules in any specimen of blood may be very rapidly (in 10′) determined. The error of the method does not exceed 2 to 3 per cent. The blood to be examined is first diluted by adding 1 part of blood to 99 parts of a solution made by mixing 1 volume of a solution of gum arabic, having a specific gravity of 1020, with 3 volumes of a solution containing equal amounts of sodic sulphate and sodic chloride, and having, also, a specific gravity of 1020. Thus diluted, the blood is introduced into an "artificial capillary," made from a thermometer tube having an elliptical bore, by grinding away the sides parallel to the long axis of the bore, thus reducing the tube to a strip of glass with a flattened canal running through it. The capacity of this capillary tube is determined by calibration with mercury, i. e., by ascertaining the weight of a quantity of mercury which occupies a given length of the tube. This artificial capillary, filled with diluted blood, is examined under the microscope, and the number of globules present in a given length of the tube determined by counting. This process is facilitated by the use of an eye-piece, containing a glass plate with squares ruled on it, which, by means of the draw tube, can be so adjusted that each square shall correspond to a given fraction of a millimetre on the capillary. Knowing, then, the capacity of the capillary, and the amount of dilution of the blood, it is easy to calculate the number of globules in a cubic millimetre of the blood in question.

When the blood of different animals is examined by this method, it is found that, in general, the higher the position in the animal series, the more numerous are the blood globules. As the size of the globules follows approximately an inverse law, it may be said in a general way that the number of globules in the blood of a given animal is inversely proportional to their size. This relation, however, is by no means constant. For example, the globules of man are at the same time less numerous and smaller than those of the dromedary and lama; and birds, though having larger and less numerous globules than mammals, gain more by the increased volume than they lose by the diminished number. The absolute number of globules is found to vary in mammals between 3,500,000 and 18,000,000 per cubic millimetre of blood. The blood of man has, on an average, about four million.

Malassez has also studied the "globular richness" of the blood in different parts of the circulatory system, and has pointed out the bearing of his results on the solution of various physiological questions. In the first place, he points out that an increased or diminished "globular richness" may be either real or apparent; *real*, when due to a formation or destruction of globules; *apparent*, when due to a diminution or increase in the amount of plasma. Arterial blood is nearly the same all over the body. Venous blood is, in general, richer in globules than arterial blood, but it differs greatly in different parts of the body. This greater globular richness is apparent rather than real, and is due to the diminution of the plasma from evaporation through the skin, from absorption by the lymphatics, and from its going to form part of various secretions. If the amount of blood flowing through an organ is increased, the venous blood becomes, in globular richness, more like the arterial, for less plasma exudes from the vessels in proportion to the amount of blood flowing through them, though the absolute amount thus exuding may be greater. For example, in the case of the submaxillary gland, irritation of the chorda tympani causes an increased flow of blood through the gland, an increased secretion of saliva, and a diminished globular richness of the venous blood. In other words, the venous blood becomes poorer in globules, i. e., richer in plasma, at the same time that the amount of fluid exuding from it is increased. This indicates, of course, that, under the influence of the irritation of the chorda tympani, the amount of blood flowing through the gland increases in a more rapid ratio than the amount of saliva secreted. The blood of the renal vein is 1·03 times richer in globules than that of the renal artery—a small difference, in view of the large amount of fluid excreted by the kidneys, but explicable when we consider the large size of the renal vessels and the immense amount of blood passing through them (938 kilo in twenty-four hours, according to Brown-Séquard).

During digestion, the blood of the mesenteric veins is poorer, but at other times richer in globules than that of the mesenteric arteries. This is, of course, accounted for by the amount of fluid absorbed from the intestine during digestion.

The blood of the splenic vein is from 1·11 to 1·21 times richer in globules than that of the splenic artery. This difference is greater than that which occurs in any of the other abdominal organs. It is probable, therefore, that the diminution of plasma is not the only cause of the difference, but that a real formation of globules takes place in the spleen. This view is strengthened by the fact that the blood of the splenic veins is found to be richest in globules during digestion, which is also the period of the greatest vascularity of the spleen, and this increased vascularity should, if the spleen were like other organs, diminish the venous globular richness.

The hepatic vein shows a diminished globular richness, which cannot be accounted for by any increase of the fluid constituents of the blood, and which indicates, therefore, a destruction of globules in the liver. This is in accordance with the known solvent action of the biliary salts on the blood globules and with the supposed formation of the coloring matter of the bile from hæmoglobin, which implies a destruction of globules.

It should be mentioned that these results, as far as regards the

splenic and hepatic veins, are not altogether in accordance with previous observations of a similar nature,* but, from the great delicacy of the method, and the care with which the experiments have been made, the author's conclusions seem to be entitled to great confidence.

The method of Malassez is likely to be of great use in pathological investigations. The author has already applied it to the study of erysipelas. He finds that, in the blood of the erysipelatous parts, the red globules are increased, and the white globules diminished in number. He finds, also, in the cellular tissue, quite a large quantity of serous fluid, containing a considerable number of white globules. He concludes, therefore, that the blood is only *apparently* richer in red globules, in consequence of fluids and white globules having passed through the vascular walls to accumulate in the cellular tissue.

Manassein has made numerous measurements of blood-globules in various animals and under various influences. He concludes that an increased temperature of the body causes a diminution in the size of the red globules, while a lowered animal temperature has the opposite effect. Hence, in fever, the globules are found to be diminished in size, while all the influences which tend to lower the animal heat (external application of cold, ingestion of alcohol, quinine or prussic acid) increase the size of the globules. The absorption of oxygen causes an increase in the size of the globules, while carbonic acid has the opposite effect.

Spontaneous Generation.

During the last few years, the old question of the origin of living organisms from non-living matter has been, under the names of archebiosis (Bastian) and abiogenesis (Huxley), brought forward and discussed with renewed energy. The great scientific importance of the problem seems to demand some reference to it in these pages, but, as the question can be regarded as physiological only in the widest sense of the word, its discussion, in this report, may perhaps be considered out of place. The reader is therefore referred to the scientific article of the *Atlantic Monthly* for December, 1873, for an excellent statement of the present condition of the controversy.

In connection with this report, it may be well to mention that the publication of the valuable "Annual Report of Henle and Meissner on the Progress of Anatomy and Physiology," which ceased with the year 1871, has been resumed, under the charge of Professors Hofmann and Schwalbe, assisted by numerous able investigators in various parts of Germany. The first volume of the new series has recently appeared, giving a *résumé* of the work done in 1872. It is in somewhat larger form than the volumes of the old series, and gives evidence that the report will be in the future even more valuable than in the past, as a work of reference for students of physiology.

---

* See Carpenter, Human Physiology, 7th Ed., p. 227.